Thermal Analysis of IC Engine Cylinder by varying Fin Gap and Thickness

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Abstract: *IC engine cylinder is the component of an IC engine which is subjected to variable temperatures very rapidly in every stroke of operation. The dissipation of heat to the surrounding is one of the major tedious tasks. The heat is generated by the combustion of fuel after a certain interval of micro seconds. Basically every four stroke engines have four strokes called suction, compression, expansion or power and exhaust stroke. In power stroke the maximum amount of heat energy is generated inside the engine and during this stroke the temperature of cylinder is so high which is to be maintained at optimum range and that is about 450-500 degree Celsius.*

Fins are the extended surfaces which are used to increase the surface area to dissipate the amount of heat rapidly and efficiently from the exterior part of the cylinder to the atmosphere. Different types of fins can be used such as rectangular, triangular and annular etc. to perform the aforesaid task. The modeling of cylinder with fins will be done in CATIA V5R12 software and then it will be imported in ANSYS thermal analysis workbench using IGES file format. The further boundary condition and analysis will be performed in ANSYS itself.

Keywords: *IC engine, cylinder, thermal analysis, fins, CATIA, ANSYS.*

1. INTRODUCTION

The text must be in English. Authors whose English language is not their own are certainly requested to have Engines are one of the most popular devices which are used in the automobiles. The invention of engine change the era of automobile sector and it was a very big revolution. Engine is heart of an automobile. The cyclic device which converts the one form of energy called chemical energy of fluid into mechanical energy is called heat engine. On macro scale there are basically two main important classifications of engines based on the combustion phenomenon i.e. internal combustion and external combustion engine. In this project our concern is with IC engine. During the combustion of fuel inside the cylinder heat is to be generated and that heat up the inside walls of the engine so the transfer of the heat is one of the major concern in IC engine. There are various types of cooling is done in IC engine based on the amount of heat generated that is water cooling and air cooling.

Air cooling is specifically used in low power engines while water cooled engines are used in heavy duty vehicles. In air cooled engines some specific geometry is attached with outer surface of the cylinder in extended fashion called fins. So fins are widely used in engines for transfer the heat from cylinder surface to surroundings. Heat is first flow in cylinder wall and then fins through conduction while the transfer of heat from fins surface to surrounding by convection.

2. LITERATURE SURVEY

Though a lot of work is being carried out in field of engine cooling and the internal combustion engine design and its various working parameters like space availability, feasibility of material chosen and the type of cooling system.

More or less the LCVs are mostly have cooling fins around the external periphery of the engine to reduce the heat levels. Many researchers dedicatedly work in this field and some of those are presented in this work as follows:

Shrivastava, S., &Upadhyay, S. Heat removal has been found to be a dramatic problem due to the continuous integration, miniaturization, densification and equipment alleviation. Heat sinks are not selected solely for their thermal performance. But also for other design parameters such as weight, cost and reliability, depending on the application. This paper describes an experimental study to improve heat transfer on a horizontal flat surface with rectangular ribs with square and circumferential perforations by forced convection. In this study, the influence of various parameters such as geometry, Reynolds number and friction factor on the heat transfer of rectangular plates with square and circular perforations is experimentally investigated. **Babu, G., & Lavakumar, M.** Analysis of the thermal properties by varying the geometry, material and thickness of the cylinder ribs. Parametric models of ribbed cylinders have been developed to predict the transient thermal behavior. In this thesis, authors concluded that using circular fins is better, but circular fins are mostly used in vertical engines than horizontal engines and also by using that, the weight of the fin body is also increases. **Gupta, S. K., Thakur, H., &Dubey, D.**In this project, our main goal is to analyze the thermal properties using different types of slat materials with slits of different sizes to improve performance and reduce costs. 3D modeling of motors with different slit sizes with the same slat size and the same number of slats in Solidworks. **Natrayan, L., Selvaraj, G., Alagirisamy, N., & Santhosh, M. S.** The design of the fins plays an important role in the heat transfer. Heat transfer from the air-cooled engine cylinder blade can be improved if the shape of the mounted blade differs from the conventional form. Improvements in heat transfer can be compared to the four engine blade geometry models by CFD analysis, and flow properties are examined for all geometries. **Patel, M. M. S., &Vora, M. N.** Examine the fact that the engine cylinder is one of the main components of the engine, which is subject to severe temperature fluctuations and thermal stresses. The main objective of the project is to analyze the thermal properties by varying the geometry, material and thickness of the ribs of the cylinders. **Tekhre, D., & Saini, J.** Author has studied various investigations on the thermal analysis of large surfaces or projections of material on the system (motor) called slats of air-cooled internal combustion engines. The heat transfer coefficient depends on the time, space, flow conditions and properties of the fluid. It was also found that a change in environmental conditions resulted in a significant change in the heat transfer coefficient and its efficiency. **Sathishkumar, K., Vignesh, K., Ugesh, N., Sanjeevaprasath, P. B., & Balamurugan, S,** Author have studied the fact that the engine is one of the important components of an automobile that is exposed to high temperatures and thermal stresses. It is clear that the results of the software theoretically indicate that the rectangular kerf ribs have a higher heat transfer rate than the hole-free, hole-shaped and V-shaped ribs since the dissipation rate.

3. MODELING AND SIMULATION

An IC engine cylinder is to be modelled with accurately the same dimensions which are observed in an actual IC engine cylinder of a MARUTI 800 car. The dimensions are taken from the old worked cylinder using the Vernier caliper used previously in car of an automobile garage.

3.1 Simulation of model

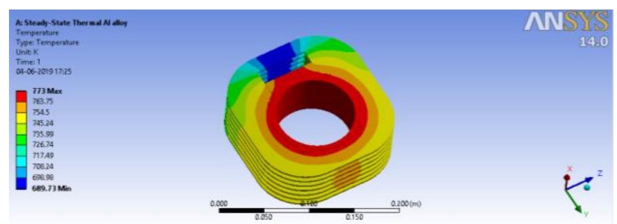

Figure 3.1: Temperature distribution for horizontal fins using Aluminium alloy as fin material

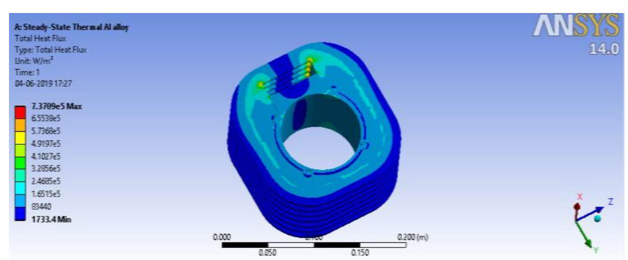

Figure 3.2: Heat flux distribution for horizontal fins using Aluminium alloy as fin material

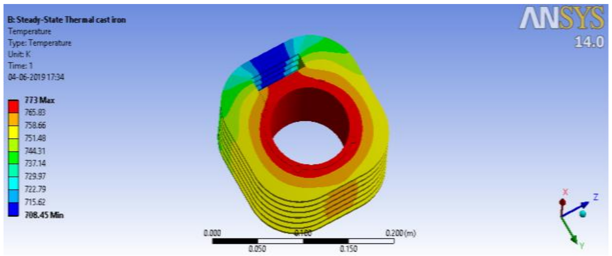

Figure 3.3: Temperature distribution for horizontal fins using Cast iron as fin material

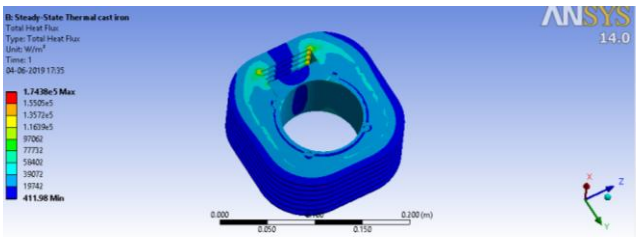

Figure 3.4: Heat flux distribution for horizontal fins using Cast iron as fin material

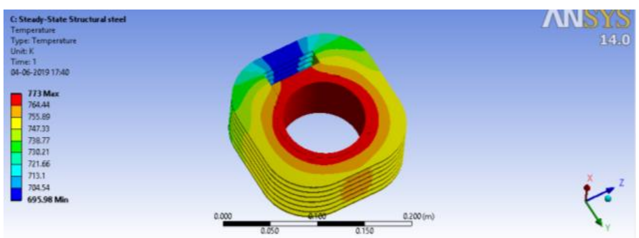

Figure 3.5: Temperature distribution for horizontal fins using Structural steel as fin material

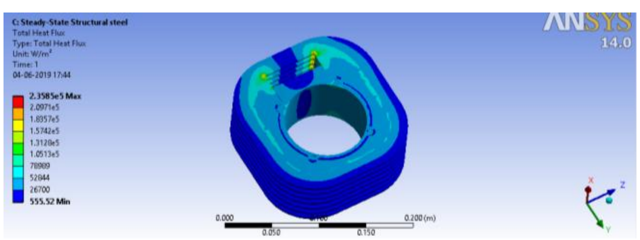

Figure 3.6: Heat flux distribution for horizontal fins using Structural steel as fin material

Figure 3.1 to figure 3.6 are the results obtained from standard geometry from IC engine cylinder. The first two figures are the temperature and heat flux distribution results obtained from aluminium alloy material. by observation the maximum and minimum temperatures are obtained as 773 k and 560 K while the maximum and minimum heat flux are 615990 w/m2 and 125.67 w/m2 respectively. Figure 3.3 and figure 3.4 are the temperature and heat flux distribution results obtained from cast iron material. Figure 3.5 and figure 3.6 are the temperature and heat flux distribution results obtained from structural steel material.

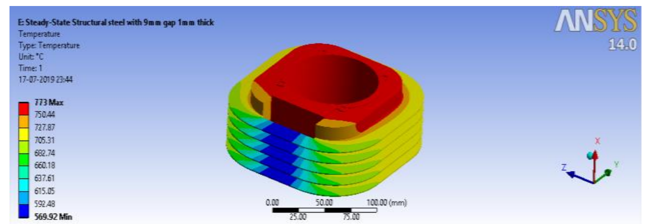

Figure 3.7: Temperature distribution for modified (9mm gap 1mm thickness) horizontal fins using Al alloy as fin material

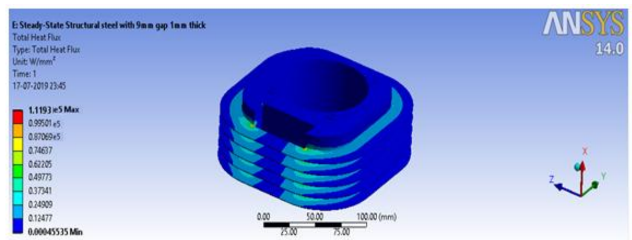

Figure 3.8: Heat flux for modified (9mm gap 1mm thickness) horizontal fins using Al alloy as fin material.

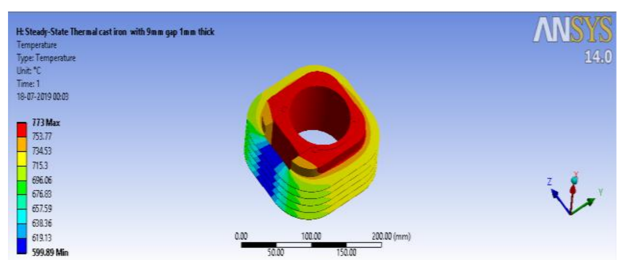

Figure 3.9: Temperature distribution for modified (9mm gap 1mm thickness) horizontal fins using cast iron as fin material.

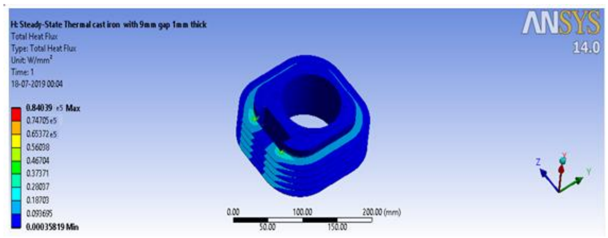

Figure 3.10: Heat flux for modified (9mm gap 1mm thickness) horizontal fins using cast iron as fin material

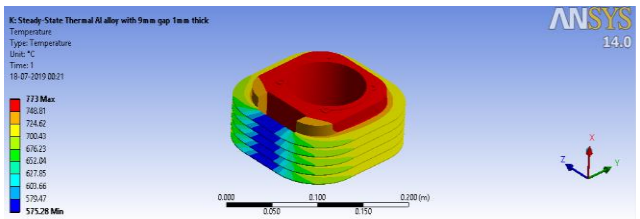

Figure 3.11: Temperature distribution for modified (9mm gap 1mm thickness) horizontal fins using structural steel as fin material.

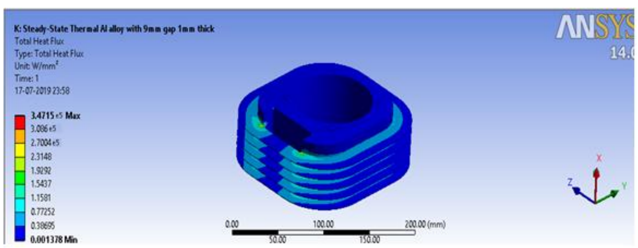

Figure 3.12: Heat flux for modified (9mm gap 1mm thickness) horizontal fins using structural steel as fin material.

Figure 3.7 to figure 3.8 are the results obtained from modified geometry (9mm gap 1 mm thick) from IC engine cylinder. The first two figures are the temperature and heat flux distribution results obtained from aluminium alloy material by observation the maximum and minimum temperatures are obtained as 773 k and 569.92 K while the maximum and minimum heat flux are 111913 w/m2 and 0.000455 w/m2 respectively. Figure 3.9 and figure 3.10 are the temperature and heat flux distribution results obtained from cast iron material. Figure 3.11 and figure 3.12 are the temperature and heat flux distribution results obtained from structural steel material.

4. RESULTS AND DISCUSSIONS

4.1 Result:

Table 4.1 Result table for standard geometry for IC engine cylinder fin (7mm gap 3 mm thick) for minimum temperature and maximum heat flux

Parameter	**Aluminum alloy**	**Cast iron**	**Structural steel**
Temperature (K)	689	708	695.9
Heat flux (W/m^2)	7.37×10^5	1.7438×10^5	2.35×10^5

Table 4.2 Result table for modified geometry (8 mm gap 2 mm thick) IC engine fin for minimum temperature and maximum heat flux

Parameter	**Aluminium alloy**	**Cast iron**	**Structural steel**
Temperature(K)	560	597.85	572
Heat flux (W/m^2)	6.1599×10^5	1.1475×10^5	1.9738×10^5

Table 4.3 Result table for modified geometry (9 mm gap 1 mm thick) IC engine fin for minimum temperature and maximum heat flux

Parameter	**Aluminium alloy**	**Cast iron**	**Structural steel**
Temperature (K)	569.92	599.89	575.28
Heat flux (W/m2)	1.11913×105	0.84039×106	3.47×105

4.2 Discussions:

The following observations can be obtained from the above two tables

1. The aluminium alloy among the three materials is having the minimum temperature in both standard and modified geometry analysis so is a good choice for selection of IC engine cylinder.
2. The aluminium alloy among three materials is also having maximum heat flux in both the geometry of IC engine cylinder so it is recommended to use this material for such kind of thermal applications.
3. The second best option among three materials is structural steel with a marginal difference in terms of

temperature distribution so can be used where light weight engine is not the point of concern.

4. The modified geometry is having all the values of minimum temperature less as compared to the presently used engine cylinder and so is proven to be used in future.
5. The modified geometry is having heat flux values in all the three material greater than the existing one and so it is prove to recommend the modified design for better heat dissipation from the cylinder surface.
6. As the gap increases up to 8mm and thickness decreases up to 2 mm the value of temperature distribution as well as heat flux are at its optimum level. As the gap increases further up to 9mm and thickness decreases up to 1 mm then it is found that that there is increase in temperature distribution and a significant decrease in heat flux and so the thickness cannot be decrease after a certain level to achieve best possible results.
7. The Maruti 800 cylinder uses grey cast iron material for fin while it is suggested from simulation and numerical results that aluminium alloy will be the best suitable material for fin geometry.

5. CONCLUSIONS

Table 5.1 Percentage deviation of minimum temperature distribution in modified geometry (8mm gap 2 mm thick) with reference to existing one

Parameter	**Minimum temperature (K) of existing geometry**	**Minimum temperature (K) of Modified geometry**	**% deviation**
Aluminium alloy	689	560	18.72
Cast iron	708	597.85	15.57
Structural steel	695.9	572	17.80

Table 5.2 Percentage deviation of heat flux of modified geometry (8mm gap 2 mm thick) with reference to existing one

Parameter	**Heat flux (W/m^2) of existing geometry**	**Heat flux (W/m^2) of Modified geometry**	**% deviation**
Aluminium alloy	7.37×10^5	6.159×10^5	16.43
Cast iron	1.7438×10^5	1.473×10^5	15.52
Structural steel	2.35×10^5	1.9138×10^5	18.56

Table 5.3 Percentage deviation of minimum temperature distribution in modified geometry (9mm gap 1 mm thick) with reference to existing one

Parameter	**Minimum temperature (K) of existing geometry**	**Minimum temperature (K) of Modified geometry**	**% deviation**
Aluminium alloy	689	569.92	17.28
Cast iron	708	599.92	15.26
Structural steel	695.9	575.28	17.33

Table5.4 Percentage deviation of heat flux of modified geometry (9mm gap 1 mm thick) with reference to existing one

Parameter	**Heat flux (W/m^2) of existing geometry**	**Heat flux (W/m^2) of Modified geometry**	**% deviation**
Aluminium alloy	7.37×105	11.193×105	34.155
Cast iron	1.738×105	1.84039×105	5.56
Structural steel	2.35×105	3.47×105	32.27

The following points are concluded on the basis of existing and modified geometry of IC engine cylinder

1. The modified geometry is providing the minimum temperature distribution at least 15-18% % lower than the existing geometry.
2. The modified geometry have a consistent percentage deviation of heat flux with respect to existing model and also is appreciable amount i.e. of the range of 5%-34% in all the three materials taken in the consideration.
3. Even for structural steel material we can see a huge difference of minimum temperature and from this results one can choose the structural steel material with this modified geometry to achieve as low value of temperature of all most 17%-18%.
4. As per the previous point 3 we can say that for mostly used mild steel material the geometry with lesser, thick fins and slightly larger gaps between two fins gives better results.

6. FUTURE SCOPE

Automobile components are enhanced in very rapid rates for better performance of engine and thus there is always a scope for new ways of enhancing quality of product. In order to achieve these targets companies are frequently modifying their pre-existing models. The present work is a simple enhancement of fin geometry to enhance the heat rejection rates. In near future a lot of more areas where one can focus on and analyze the effect of modification with the existing models.

The future scope may be in many directions and some of them are stated as under:

1. More advanced materials can be taken into consideration with better thermal conductivity and strength.
2. Some more kind of fin profiles can be made like vertical fins or some annular type of arrangements can be analysed in near future.
3. The transient thermal analysis can be performed to see the change in heat flux in dynamic conditions of vehicle.
4. Steps may be applied in ANSYS solver to see the rate of heat dissipated with respect to time.
5. The type of meshing and mesh size are also very important parameters which can be modified in different zones of IC engine cylinder to obtain even more accurate results.

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